Wind and Solar Utility scale projects in North America are typically quite large, with miles of buried cables transmitting energy to and from the substation. Multiple factors can converge to create erratic faults, catastrophic failures, and other maintenance challenges.

The collection system is typically arranged in radial strings of turbines connected to a collection point, typically at a collector substation. The most common collection voltage is 34.5kV, but other voltages may be encountered. These cable systems are commonly aluminum conductors with water tree retardant cross-linked polyethylene (TR-XPLE) solid dielectric insulation, copper concentric (flat or round) wire neutrals, and a protective polyethylene (PE) outer jacket.

Due to the length of some circuits, the cable segments are spliced together in various configurations with pre-molded, heat shrink or cold shrink accessories and directly buried in the earth

Modern cables, insulated with plastics, do not fail by the same method as previous generations of cables. Previous generations of cables were insulated with materials that could absorb water or had limited value degradable insulations (Paper, Oil). A common test was therefore to validate whether the insulation was still acceptable through withstand tests or electrical withstand measurement, tests which have less value in modern cable systems.

The insulating plastics in extruded insulated cable systems should maintain their dielectric withstand strength for the life of the cable unless they are degraded. Extruded cables fail due to unmanaged electrical stresses that create partial discharges which can lead to a dielectric failure of the insulation system. Partial Discharges can be identified by three distinct causes: manufacturing created defects, workmanship (handling damage, contaminants, and dimensional issues)

As previously stated, the most common withstand tests that may be found in use at wind and solar projects are DC Insulation Resistance and VLF tests.

An AC withstand test or VLF high potential withstand test includes the application of up to 300% over operating voltage VLF source (alternating polarity typically every 5 seconds or 0.1Hz) for a duration of typically 15, 30 or 60 minutes. If no fault occurs, the cable system is believed to be serviceable. Historically, VLF withstand testing was commonly used as a low-cost commissioning and maintenance test, however, many owners restrict the use of VLF voltage sources to operating voltage level for just a few minutes as a proof test before energizing the circuit.

DC Insulation Resistance Tests are typically performed with a megohmmeter. Since the test uses voltages of the cable system it is considered to be a non-destructive test. Typically, 5 or 10kV DC is applied for approximately one minute or until the voltage stabilizes, whichever comes first. For good insulation, the resistance usually reads in at least the megohm, and often in the gig ohms, or higher range. Readings in the ohm range are not acceptable, and readings in the kilo-Ohm range usually indicate an insulation problem. The absolute value of the reading is very subjective and not of significance and since the test cannot detect the vast majority of defects in cables and accessories it is of limited value. It is an effective method of ascertaining that all "Shorts and Grounds" have been removed from the system prior to energization. Comparing phases to determine if one has a significantly lower resistance may be useful for isolating faults.

As previously stated, common diagnostic tests in use on wind and solar projects include offline and online PD, offline tangent delta, and DC insulation resistance testing.

Tangent delta (TD) typically uses a VLF voltage source applied at a few voltage levels while measuring any losses in the cable system. The test provides a relative measure of how the cable system compares to a perfect, lossless, capacitor. Since the test is very sensitive to losses associated with conductivity, it may be useful for detecting very specific conditions, especially in older projects. Tangent delta testing can also detect water trees and corroded neutrals in the cable system. If owners are interested in confirming if losses have increased in the cable over time, Tan-Delta gives an average dielectric loss value which can mask discrete defects. Tangent delta testing is of limited value in locating defects and other methods of testing may be needed to identify the precise location of defects. Tan-Delta gives an average capacitive value which can mask discrete defects.

Offline 50/60 Hz partial discharge testing is often specified as a commissioning test for new wind and solar projects however it has been used extensively to test aged cables as well. PD testing is widely used in the wind and solar industry because of its ability to provide a direct comparison to the original factory quality control test and can provide an accurate location of the defect. In Offline PD testing, a power frequency Hi-

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